(iii) Use four-ply silicone-fiberglass fabric with a temperature rating of at least 315 °C for flexible connectors. You may use connectors with a spring-steel wire helix for support and you may use Nomex™ coverings or linings for durability. You may also use any other material with equivalent permeation-resistance and durability, as long as it seals tightly around tailpipes and does not react with exhaust.

(iv) Use stainless-steel hose clamps to seal flexible connectors to the outside diameter of tailpipes, or use clamps that seal equivalently.

(v) You may use additional flexible connectors to connect to flow meters and sample probe locations.

(2) *Raw exhaust tubing.* Use rigid 300 series stainless steel tubing to connect between flexible connectors. Tubing may be straight or bent to accommodate vehicle geometry. You may use ''T'' or ''Y'' fittings made of 300 series stainless steel tubing to join exhaust from multiple tailpipes, or you may cap or plug redundant tailpipes if the engine manufacturer recommends it.

(3) *Exhaust back pressure.* Use connectors and tubing that do not increase back pressure so much that it exceeds the manufacturer's maximum specified exhaust restriction. You may verify this at the maximum exhaust flow rate by measuring back pressure at the manufacturer-specified location with your system connected. You may also perform an engineering analysis to verify proper back pressure, taking into account the maximum exhaust flow rate expected, the field test system's flexible connectors, and the tubing's characteristics for pressure drops versus flow.

(b) For vehicles or other motive equipment, we recommend installing PEMS in the same location where passenger might sit. Follow PEMS manufacturer instructions for installing PEMS in vehicle cargo spaces, vehicle trailers, or externally such that PEMS is directly exposed to the outside environment. Locate PEMS where it will be subject to minimal sources of the following parameters:

(1) Ambient temperature changes.

(2) Ambient pressure changes.

(3) Electromagnetic radiation.

(4) Mechanical shock and vibration.

(5) Ambient hydrocarbons—if using a FID analyzer that uses ambient air as FID burner air.

(c) *Mounting hardware.* Use mounting hardware as required for securing flexible connectors, exhaust tubing, ambient sensors, and other equipment. Use structurally sound mounting points such as vehicle frames, trailer hitch receivers, and payload tie-down fittings. We recommend mounting hardware such as clamps, suction cups, and magnets that are specifically designed for vehicle applications. We also recommend considering mounting hardware such as commercially available bicycle racks, trailer hitches, and luggage racks.

(d) *Electrical power.* Field testing may require portable electrical power to run your test equipment. Power your equipment, as follows:

(1) You may use electrical power from the vehicle, up to the highest power level, such that all the following are true:

(i) The vehicle power system is capable of safely supplying your power, such that your demand does not overload the vehicle's power system.

(ii) The engine emissions do not change significantly when you use vehicle power.

(iii) The power you demand does not increase output from the engine by more than 1% of its maximum power.

(2) You may install your own portable power supply. For example, you may use batteries, fuel cells, a portable generator, or any other power supply to supplement or replace your use of vehicle power. However, you must not supply power to the vehicle's power system under any circumstances.

§ 1065.915 PEMS instruments.

(a) *Instrument specifications.* We recommend that you use PEMS that meet the specifications of subpart C of this part. For field testing of for laboratory testing with PEMS, the specifications in the following table apply instead of the specifications in Table 1 of § 1065.205.

TABLE 1 OF § 1065.915—RECOMMENDED MINIMUM PEMS MEASUREMENT INSTRUMENT PERFORMANCE

Measurement	Measured quantity symbol	Rise time and fall time	Recording update frequency	Accuracy [1]	Repeatability [1]	Noise [1]
Engine speed transducer.	f_n	1 s	1 Hz means	5.0% of pt. or 1.0% of max.	2.0% of pt. or 1.0% of max	0.5% of max.
Engine torque estimator, BSFC (This is a signal from an engine's ECM).	*T* or *BSFC*	1 s	1 Hz means	8.0% of pt. or 5% of max.	2.0% of pt. or 1.0% of max	1.0% of max.
General pressure transducer (not a part of another instrument).	*p*	5 s	1 Hz	5.0% of pt. or 5.0% of max.	2.0% of pt. or 0.5% of max	1.0% of max.
Atmospheric pressure meter.	p_{atmos}	50 s	0.1 Hz	250 Pa	200 Pa	100 Pa.
General temperature sensor (not a part of another instrument).	*T*	5 s	1 Hz	1.0% of pt. K or 5 K.	0.5% of pt. K or 2 K	0.5% of max 0.5 K.
General dewpoint sensor.	T_{dew}	50 s	0.1 Hz	3 K	1 K	1 K.
Exhaust flow meter	$\dot{n}$	1 s	1 Hz means	5.0% of pt. or 3.0% of max.	2.0% of pt	2.0% of max.
Dilution air, inlet air, exhaust, and sample flow meters.	$\dot{n}$	1 s	1 Hz means	2.5% of pt. or 1.5% of max.	1.25% of pt. or 0.75% of max	1.0% of max.
Continuous gas analyzer.	*x*	5 s	1 Hz	4.0% of pt. or 4.0% of meas.	2.0% of pt. or 2.0% of meas	1.0% of max.
Gravimetric PM balance.	m_{PM}	N/A	N/A	*See* § 1065.790	0.5 μg	N/A
Inertial PM balance.	m_{PM}	5 s	1 Hz	4.0% of pt. or 4.0% of meas.	2.0% of pt. or 2.0% of meas	1.0% of max.

[1] Accuracy, repeatability, and noise are all determined with the same collected data, as described in § 1065.305, and based on absolute values. ''pt.'' refers to the overall flow-weighted mean value expected at the standard; ''max.'' refers to the peak value expected at the standard over any test interval, not the maximum of the instrument's range; ''meas'' refers to the actual flow-weighted mean measured over any test interval.

(b) *Redundant measurements.* For all PEMS described in this subpart, you may use data from multiple instruments to calculate test results for a single test. If you use redundant systems, use good engineering judgment to use multiple measured values in calculations or to disregard individual measurements. Note that you must keep your results from all measurements, as described in § 1065.25. This requirement applies whether or not you actually use the measurements in your calculations.

(c) *Field-testing ambient effects on PEMS.* PEMS must be only minimally affected by ambient conditions such as temperature, pressure, humidity, physical orientation, mechanical shock and vibration, electromagnetic radiation, and ambient hydrocarbons. Follow the PEMS manufacturer's instructions for proper installation to isolate PEMS from ambient conditions that affect their performance. If a PEMS is inherently affected by ambient conditions that you cannot control, you must monitor those conditions and adjust the PEMS signals to compensate for the ambient effect. The standard-setting part may also specify the use of one or more field-testing adjustments or ''measurement allowances'' that you apply to results or standards to account for ambient effects on PEMS.

(d) *ECM signals.* You may use signals from the engine's electronic control module (ECM) in place of values measured by individual instruments within a PEMS, subject to the following provisions:

(1) *Recording ECM signals.* If your ECM updates a broadcast signal more frequently than 1 Hz, take one of the following steps:

(i) Use PEMS to sample and record the signal's value more frequently—up to 5 Hz maximum. Calculate and record

the 1 Hz mean of the more frequently updated data.

(ii) Use PEMS to electronically filter the ECM signals to meet the rise time and fall time specifications in Table 1 of this section. Record the filtered signal at 1 Hz.

(2) *Omitting ECM signals.* Replace any discontinuous or irrational ECM data with linearly interpolated values from adjacent data.

(3) *Aligning ECM signals with other data.* You must perform time-alignment and dispersion of ECM signals, according to PEMS manufacturer instructions and using good engineering judgment.

(4) *ECM signals for determining test intervals.* You may use any combination of ECM signals, with or without other measurements, to determine the start-time and end-time of a test interval.

(5) *ECM signals for determining brake-specific emissions.* You may use any combination of ECM signals, with or without other measurements, to estimate engine speed, torque, and brake-specific fuel consumption (BSFC, in units of mass of fuel per kW-hr) for use in brake-specific emission calculations. We recommend that the overall performance of any speed, torque, or BSFC estimator should meet the performance specifications in Table 1 of this section. We recommend using one of the following methods:

(i) *Speed.* Use the engine speed signal directly from the ECM. This signal is generally accurate and precise. You may develop your own speed algorithm based on other ECM signals.

(ii) *Torque.* Use one of the following:

(A) *ECM torque.* Use the engine-torque signal directly from the ECM, if broadcast. Determine if this signal is proportional to indicated torque or brake torque. If it is proportional to indicated torque, subtract friction torque from indicated torque and record the result as brake torque. Friction torque may be a separate signal broadcast from the ECM or you may have to determine it from laboratory data as a function of engine speed.

(B) *ECM %-load.* Use the %-load signal directly from the ECM, if broadcast. Determine if this signal is proportional to indicated torque or brake torque. If it is proportional to indicated torque, subtract the minimum %-load value from the %-load signal. Multiply this result by the maximum brake torque at the corresponding engine speed. Maximum brake torque versus speed information is commonly published by the engine manufacturer.

(C) *Your algorithms.* You may develop and use your own combination of ECM signals to determine torque.

(iii) *BSFC.* Use one of the following:

(A) Use ECM engine speed and ECM fuel flow signals to interpolate brake-specific fuel consumption data, which might be available from an engine laboratory as a function of ECM engine speed and ECM fuel signals.

(B) Use a single BSFC value that approximates the BSFC value over a test interval (as defined in subpart K of this part). This value may be a nominal BSFC value for all engine operation determined over one or more laboratory duty cycles, or it may be any other BSFC that we approve. If you use a nominal BSFC, we recommend that you select a value based on the BSFC measured over laboratory duty cycles that best represent the range of engine operation that defines a test interval for field-testing.

(C) You may develop and use your own combination of ECM signals to determine BSFC.

(iv) *Other ECM signals.* You may ask to use other ECM signals for determining brake-specific emissions, such as ECM fuel flow or ECM air flow. We must approve the use of such signals in advance.

(6) *Permissible deviations.* ECM signals may deviate from the specifications of this part 1065, but the expected deviation must not prevent you from demonstrating that you meet the applicable standards. For example, your emission results may be sufficiently below an applicable standard, such that the deviation would not significantly change the result. As another example, a very low engine-coolant temperature may define a logical statement that determines when a test interval may start. In this case, even if the ECM's sensor for detecting coolant temperature was not very accurate or repeatable, its output would never deviate so far as to significantly affect when a test interval may start.